HISTORY AND CONSTRUCTION

OF THE

ELECTRICAL SUBSTATION OF THE PENNSYLVANIA RAILROAD

AT

LANDOVER, MARYLAND

BY LOUIS FRANCIS FLAGG

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MAY 3, 1935

INTRODUCTION

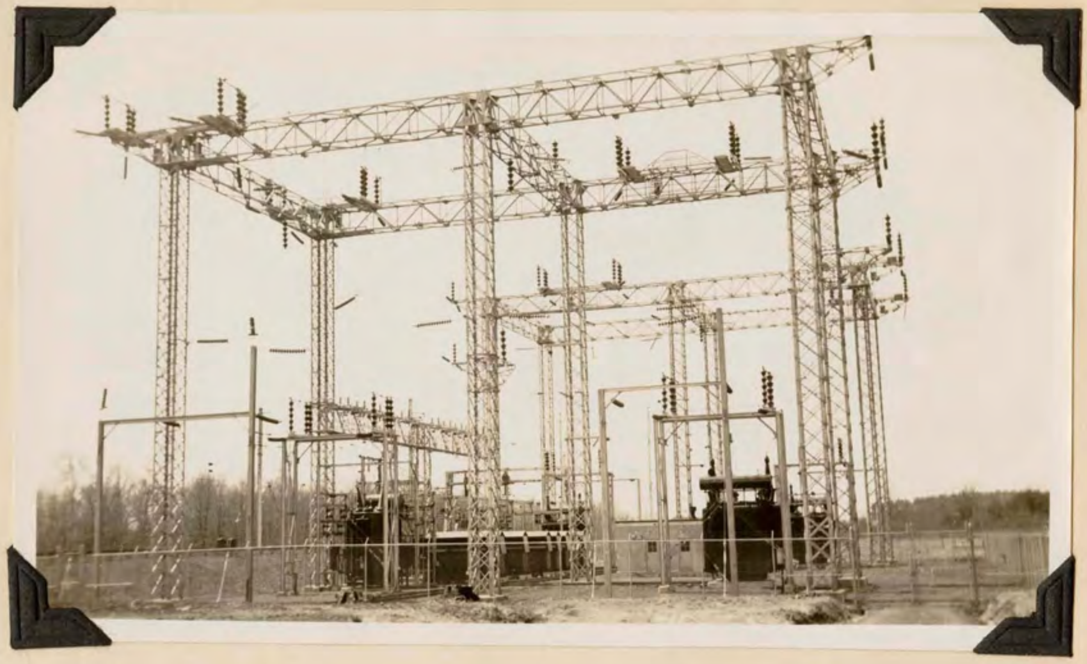
The author has attempted to present in this thesis a clear conception of the part that Landover Substation plays in the electrification of the Pennsylvania Railroad. The subject is covered in as much detail as available information would permit. This was done with the idea of using the thesis as a future reference since the details concerning the substation are so difficult to obtain.

Many difficulties were encountered in obtaining information for this thesis because much of the apparatus was designed especially for the electrification and hence very little is written about it. The plans of the substation are secretive and are not obtainable. The cost is also unobtainable, and estimates varied from a quarter to a half million dollars.

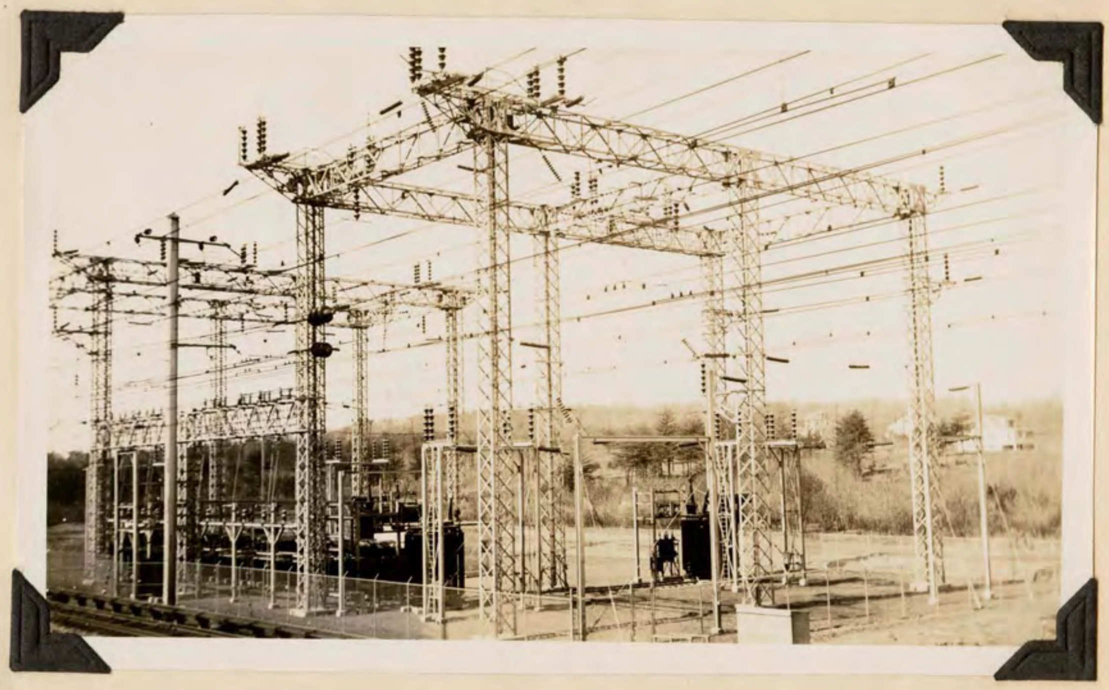
In order to make this presentation clearer and more interesting, diagrams and pictures were added.

The author suggests that the reader might get a better understanding of this project if the thesis " The History and Methods of Electrification of the Pennsylvania Railroad between Baltimore and Washinton, D.C." by G. H. Ludwig is read first.

~~SUMMARY~~ Contents



Substation from road leading to it



Substation from box car across the tracks

HISTORY AND CONSTRUCTION

The electrical substation of the Pennsylvania Railroad at Landover, Maryland is an important link in a chain of substations necessary for the successful electrification of the railroad. When the Pennsylvania Railroad decided upon electrification, the entire project was turned over to the electrification designers, Gibbs and Hill of New York. They were confronted with the problem of supplying power to the trains over long stretches unless intermediate power supply stations were added. They decided to draw from the large power supply at Safe Harbor and transmit it at high voltage to electrical substations placed at strategic points approximately ten miles apart. Landover is one of the key points on the railroad because it is there that the passenger and freight lines into Washington split. It also is about ten miles from the nearest main control point in either direction. Therefore it was essential to use Landover as one substation location.

After Landover had been decided upon as the general location its exact position had to be determined and a center line laid down. This line and a bench mark in the vicinity along with the blue print plans of the substation formed the basis from which the station was built. The job of surveying this plot was given to an inspector whose duty it was to see that everything went into the substation according to the blue prints unless alterations were necessary. To actually put in the materials and control the crew a foreman was assigned. The crew itself was made up of men who had worked for the division previously, some of them furloughed conductors and engineers. However the Landover crew also had a few outside men who were more experienced. These were brought in by giving them a division job and then furloughing them after one day, thus covering the rules.

Train with new type electric locomotive

Steam train under a signal

New type spot signal

Placing concrete foundations

Clearing the land for the substation was done in April 1934 but actual work on the station was started about the middle of June 1934. One difficulty arose almost immediately thereafter. The substation was to be built over a section of a state road and permission to close this road could only be obtained through a court order. The State Roads Commission agreed to this but court did not convene until September. In the meantime a road was built around the station and a detour sign placed on the old road although it was not officially closed. The court order granting the road right of way to the railroad was finally issued about the first of October. In the meantime work on the substation had progressed without delay. In fact all the foundations had been placed and most of the steel work erected at that time.

The actual laying out of the substation was begun by surveying to obtain all foundation locations. Then followed excavating which was done entirely by manual labor. After the excavation another difficulty was realized. Due to the swampy region the clay was so soft that a reenforcement rod could be shoved in out of sight. To eliminate this difficulty the holes were dug deeper and about a foot of stone was placed on top of the soft clay before the concrete was poured.

The concrete for this job was mixed by the crew itself with a ratio of 1:2.5:3.5. The steel work, both high and low structures, was placed in the foundations by huge cranes. The 90 foot steel columns were carefully trued up with instruments and fastened together with the cross pieces. After they were all linked together there was very little chance of any movement to cause a change in alignment.

Before any of the heavy equipment was brought in a service track which branched off the main track was laid into the substation. Then four tracks were laid perpendicular to the service track, one leading to each

A

B

C

D

Placing steel work with cranes(A, B, C)
Working on "H" switches(D)

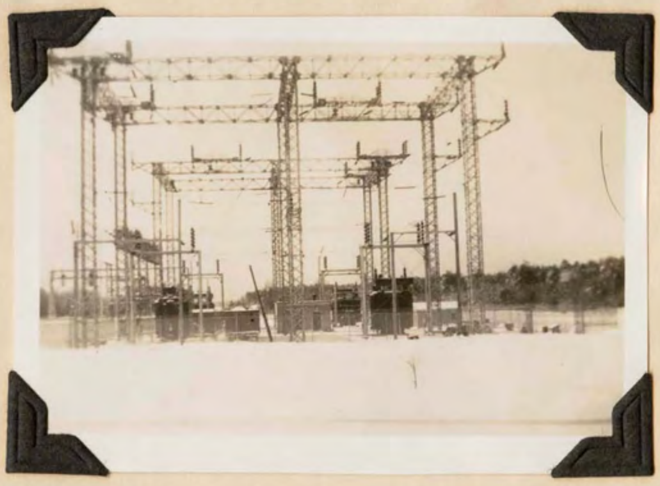
main transformer. These large transformers were brought into the station on flat-cars by way of the service track. Each was then lowered to its own track and moved along the track until directly over its foundation where it was to be permanently located. Circuits breakers were also brought in by train and placed on their foundations from there. All other heavy equipment was treated likewise.

The control building located directly in the center of the substation was built of cement blocks which were made by using cinders instead of stone for the coarse aggregates. The building is a one story structure about 22 feet wide, 26 feet long, and 13 feet high with concrete floors and roof. It has three rooms in all. One takes up about half the building and contains a switch control board and a motor-generator set. The other two take up the remaining half about evenly. One of these is the battery room and the other just a storeroom.

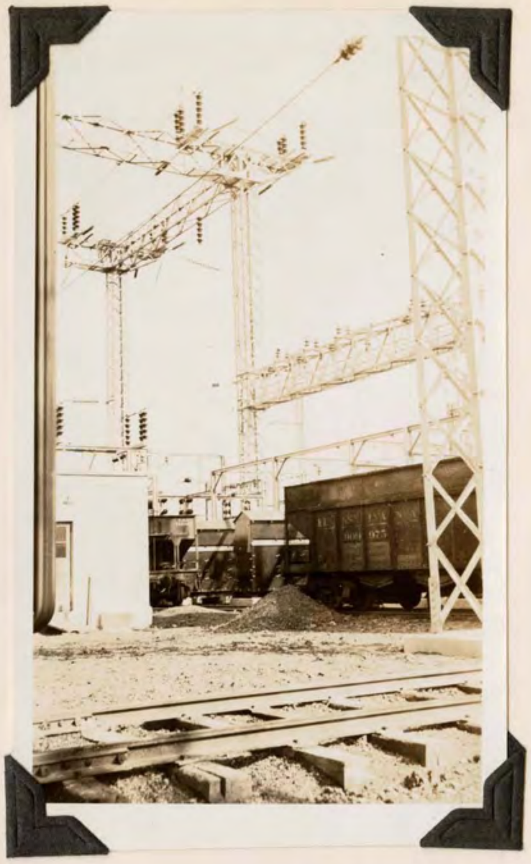
In order to improve the surface of the substation ground about 8 inches of cinders were placed on top of it. These were brought in by train and spread over the entire inclosure. A high fence with barbed wire at the top was placed around the entire substation to keep inquisitive people and animals out of danger.

When the substation had been completed sufficiently a D.C. test was made. This was done at Landover about the middle of October. Before the station was actually placed in service it was also necessary to make an A.C. test as a final check on all apparatus and circuits. This was done from January 18 to 25, 1935. For this test the substation was energized on January 18 at about nine o'clock in the morning for the first time. The control of the station was turned over to the tower board on February 2 and under normal conditions has operated from there ever since. The entire project minus a few details

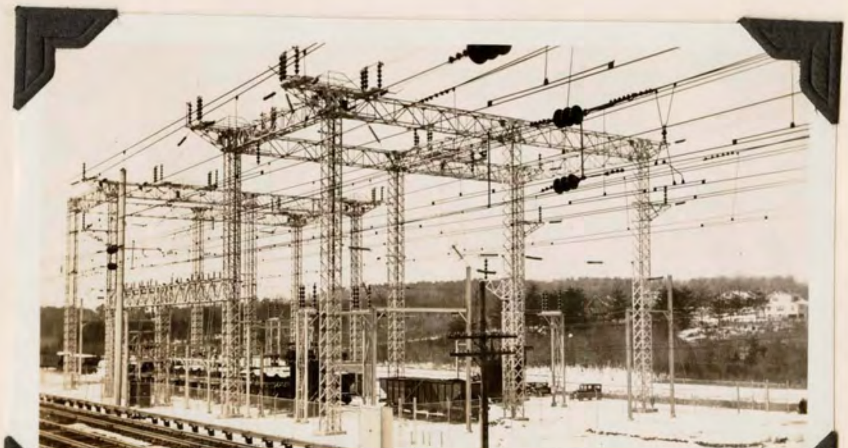
Substation in early stages of construction



Substation when practically completed

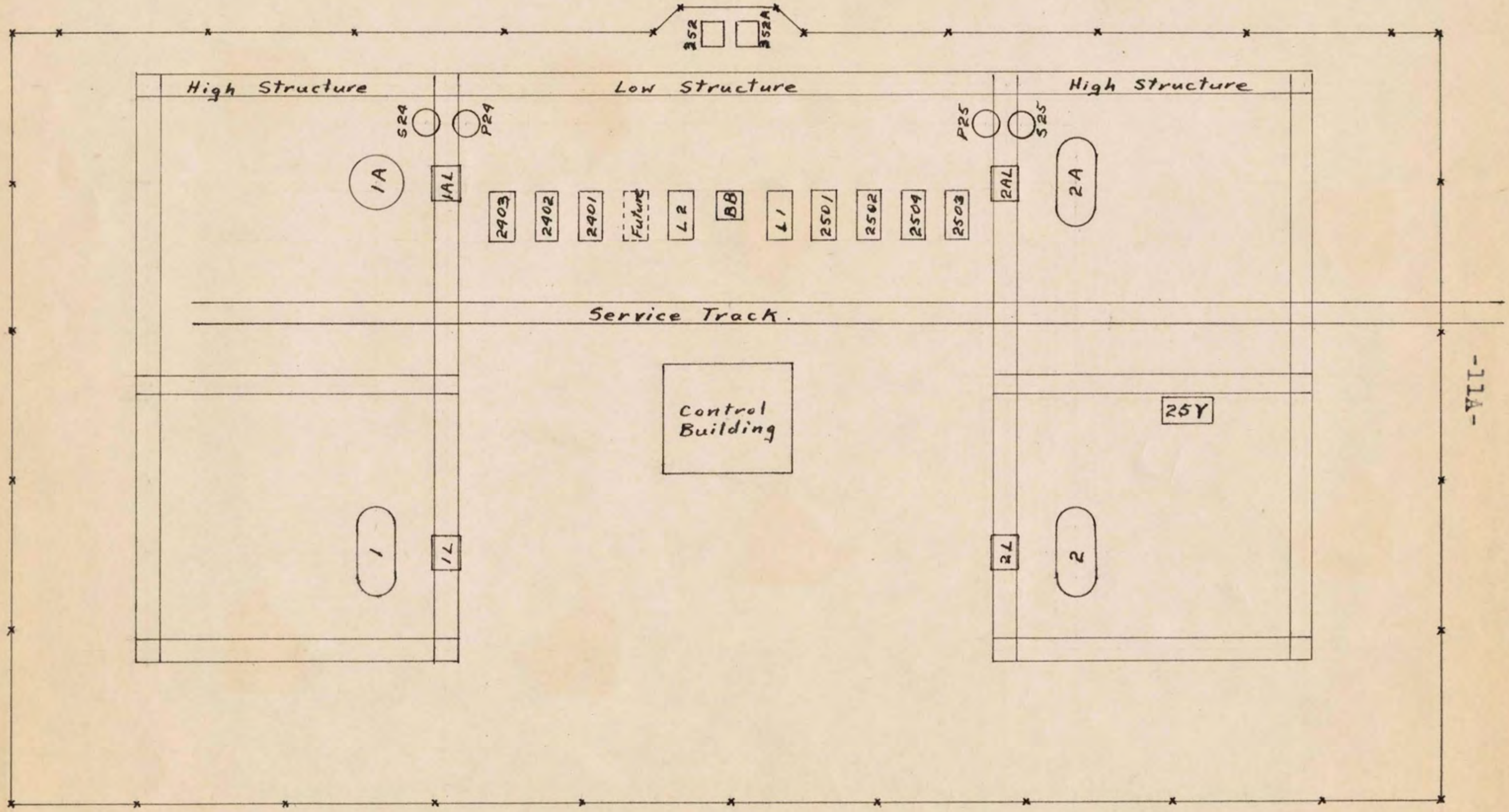


Internal view before completion



Substation just before completion

from box car across tracks



LANDOVER SUBSTATION

Ground Plan.

such as a lightning pole which has not been placed yet was officially completed about the middle of March, 1935.

At the present time the substation is controlled from the tower but an electrician maintainer and his helper work at the station 8 hours a day for 6 days a week. Their job is to inspect and take care of the substation. They may also be called on to help in case of trouble, but up to the present time Landover Substation has had no serious trouble of any kind.

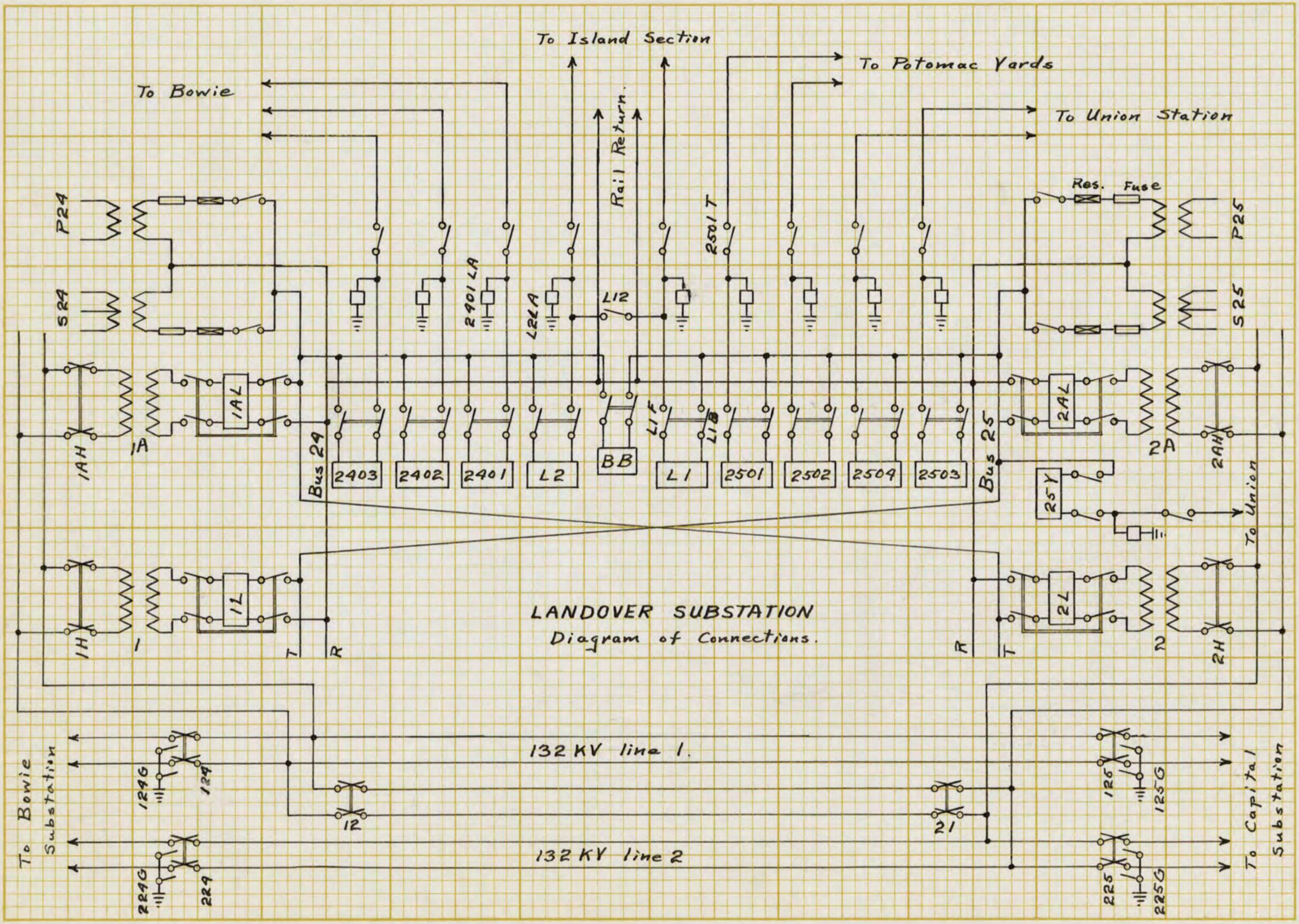
ELECTRICAL LAYOUT *

In order to more easily understand the layout of the substation it is first necessary to understand the system of numbers used throughout the entire chain of substations. Each substation is designated by a number, these numbers running in sequence going south. Thus Severn Substation is number 22, Bowie is number 23, Landover is number 24, and Capital is number 25. All transmission lines between substations are designated by the number of the more southern station. Thus the two transmission lines, called 1 and 2, are called 124 and 224 between Bowie and Landover. Between Landover and Capital these lines are 125 and 225. This system makes it easier for designating switches and other apparatus.

High Side Layout

Now the first consideration in the electrical layout of the substation is the means of bringing power into the station. This is done with the two transmission lines, 124 and 224, carrying 132,000 volts A.C. The first switches on these 132 KV lines are ground switches 124G and 224G. On the same steel framework the lines must pass through main line switches 124 and 224.

* See diagram of connections



LANDOVER SUBSTATION
Diagram of Connections.

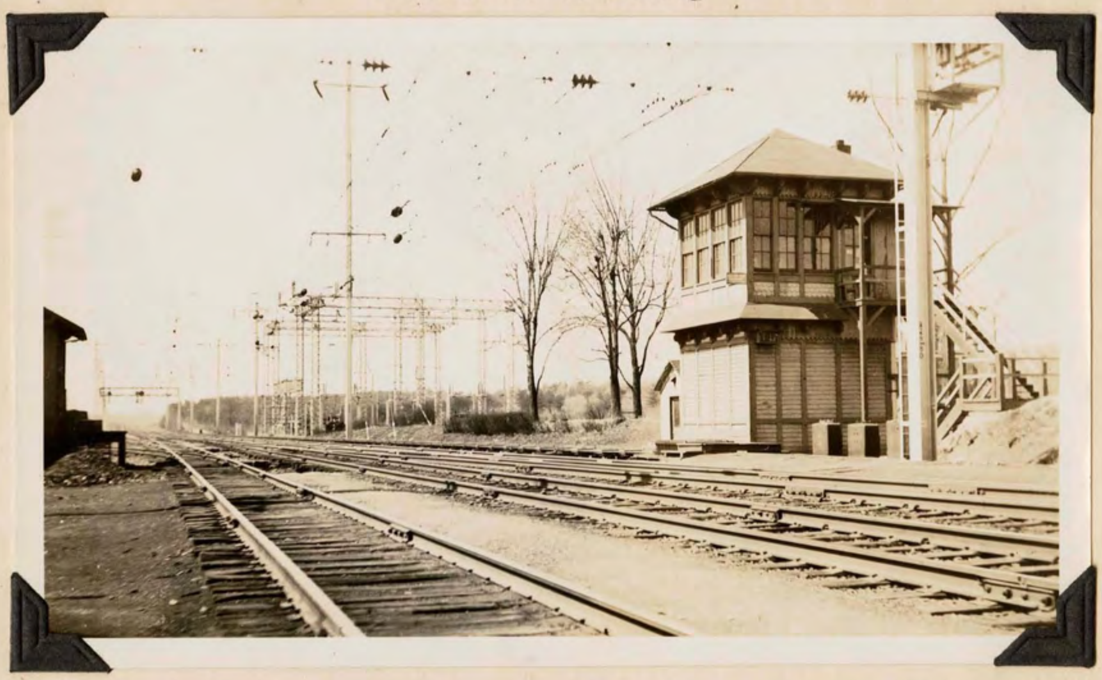
From there these lines pass to the other side of the station where they pass through switches 125 and 225. There are also ground switches beyond, numbers 125G and 225G. The lines lead from there to Capital Substation in Washington. Thus it is possible by opening switches 125 and 225 to cut off the entire power supply to Capital. Likewise by opening 124 and 224 the supply to Landover is cut off. The 132 KV lines are tied together through two switches, the switch nearest line 1 is called 12 and that nearest line 2 is 21, showing that the switches are from lines 1 to 2 and 2 to 1 respectively. A lead taken off the 132 KV bus of line 1 goes to transformers 1 and 1A after passing through the so called "H" switches 1H and 1AH. A lead taken off the 132 KV line 2 goes to transformers 2 and 2A through the switches 1H and 2AH. That completes the high side (132 KV) layout of the substation.

Low Side Layout

The secondary of each transformer is connected to a low side bus and a rail return bus through an "L" circuit breaker. Each "L" breaker is numbered according to the transformer which it connects. They are 1L, 1AL, 2L, 2AL. Each of these breakers is isolated by switches to afford protection while working on it. There are two 12 KV buses, numbers 24 and 25. Alternate transformers are connected to these. That is, transformers 1 and 2A supply bus 25 while 1A and 2 supply bus 24. Connected in this fashion the 132 KV line 1 supplies bus section 25 through transformer 1 and bus section 24 through 1A. Similarly line 2 supplies both buses through 2A and2. The bus sections may be connected together by the "BB" bus-tie circuit breaker which is also isolated by switches. All the trolley feeders are taken off the 12 KV bus sections through JRA circuit breakers. These breakers are numbered according to the bus section and the trolley supplied through the breaker. Thus the

breaker feeding the trolley on track 1 going north is 2401, for track 2 it is 2402, and for track 3 it is 2403. All feeders going north are from bus 24 and those going south from bus 25. There are four tracks leading south from Landover, two down the Anacostia Branch (freight line) to Potomac Yards and two down the Magruder Branch (passenger line) to Union Station. The freight line is fed through breakers 2501 and 2502, and the passenger line is fed through 2503 and 2504. Another line leading south to a sectionalizing switch between Landover and Union Station is fed through 25Y. There are also two other JRA breakers, L1 from bus 25 and L2 from bus 24, that feed an island section at Landover. This is merely a feed for a section containing switches that are not connected to the main trolleys. The feeders from L1 and L2 are connected by a switch, L12, so both may be operated from either bus section. Each JRA breaker may be isolated by its "B" and "F" switches. The "B" switch disconnects the breaker from its bus section and the "F" from its trolley feeders. There is also a "T" switch in each trolley feeder to permit work on the trolley feeder right up to the point where it leaves the station. The "B", "F", and "T" switches are numbered the same as the breakers. Thus breaker 2401 is isolated by opening 2401B and 2401F. In addition to the trolley feeders each 12 KV bus supplies a service transformer and a potential transformer. These are numbered S24, P24, S25, and P25. Each service transformer has 220 volts across its secondary with a center tap to give 110 volts off each side. This is used to run a motor-generator set and for lighting. Each potential transformer has 110 volts across its secondary and is used for relay operation. The rail return bus is connected to the rail by underground cable. One side of the secondary of each main transformer is connected to the rail return bus. One side of the primary of the S and P transformers is also connected to the rail return bus.

Control building



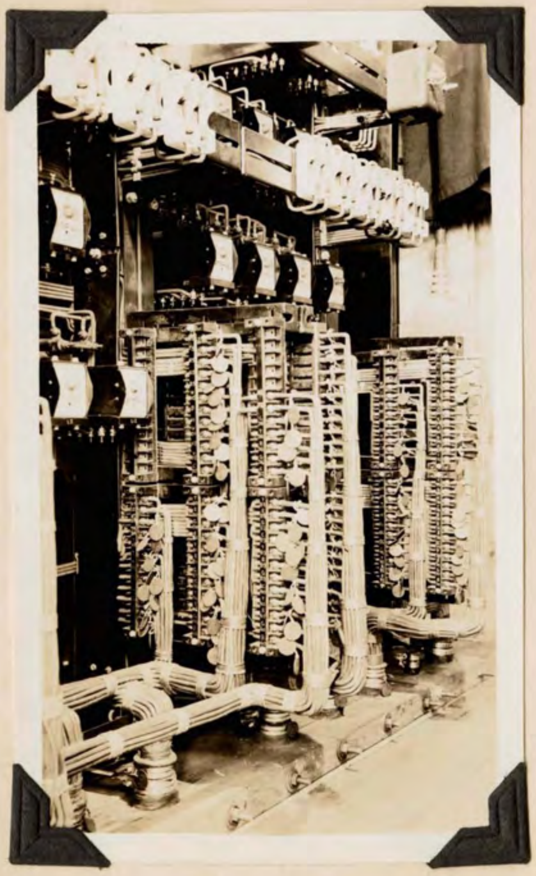
Interlock tower with substation in background looking south from Landover crossing

Signal relays in interlocking tower

CONTROL

In order to give a simple and dependable control of all equipment D.C. power is used to operate all breakers and high side switches. This makes remote control possible when desirable. All such switches and breakers are operated from a control board located in the control building of the substation. This board carries many of the relays and the control handles for operation of breakers and motor-operated switches. A one line drawing of the diagram of connections is on the board in two colors, red for 132 KV lines and yellow for 12 KV lines. On these lines are placed the control handles in their proper positions in the circuit. With each control handle are two lights, one green and one red. When the switch or breaker is closed the red light is on, when open the green light is on. The handle also has a lockout position in which no light shows. Thus the operator can see at a glance which circuits are closed and which open.

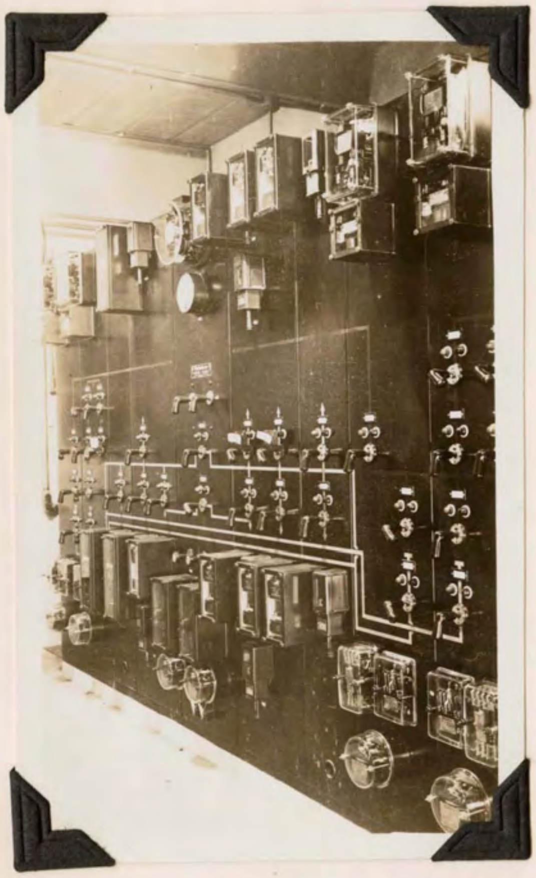
However, to keep perfect control over an entire system of substations such as exists in the single stretch of track from Washington to Baltimore, it would not be plausible to allow each substation operator to close and open switches without supervision. Therefore no change may be made in the breakers and switches of a substation without permission or orders for such a change from the power director's office in Baltimore. This office contains an enormous board on which is the diagram of all tracks and substations from Wilmington, Delaware to the Potomac Yards in Alexandria, Virginia. Every control switch over that distance is shown by a green or red light. These lights are controlled by the power director by means of switch buttons on a small table switchboard. The diagram is so connected that if any section of track has a dead trolley a series of white lights show on that section of the board. Thus the power director can see which

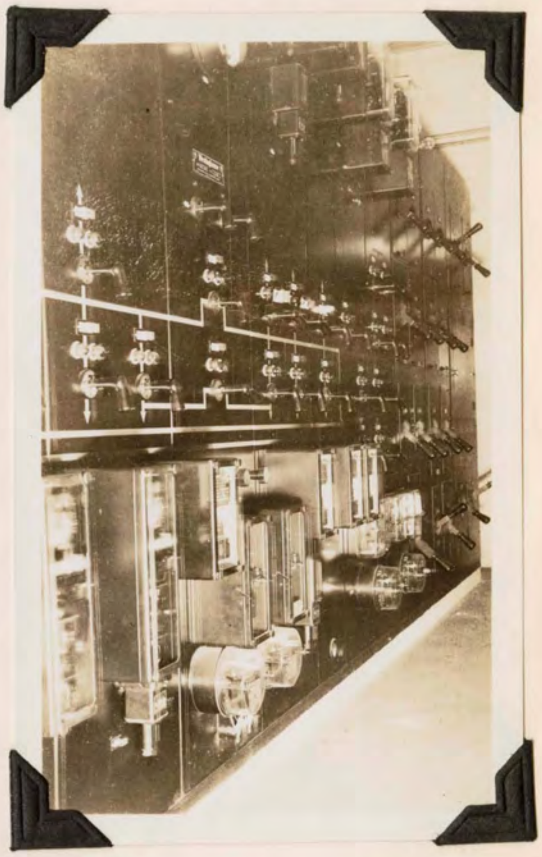


Tower control board

switches may be opened or closed without cutting the power on any section of track. In order for the substation maintainer to work on a breaker, he must first call the power director to get permission. If the breaker may be opened without interfering with the power on the trolley involved, the power director gives permission to open the breaker. After opening the breaker the maintainer calls the power director back informing him that the breaker is open. The power director then changes the light for that breaker from red to green. This long proceedure enables the power director to keep perfect control of the whole system. The substation telephone has three circuits for control purposes, one to the power director, one to the interlocking tower, and one a PBX exchange for outside calls.

So that it would not be necessary to keep a special operator in each substation day and night, a switchboard was placed in the nearby interlocking tower which must have a man day and night to control track switches. This tower control board has the same circuits, control handles, and lights as the substation board but is much smaller because it has only two relays. There are six meters on the tower board. Four of these are ammeters, one for each main transformer. The other two are voltmeters, one for bus 24 and one for 25. These meters make it easier for the tower operator to compare voltages and currents without switching as is necessary on the station board. The two small lights on the board act as ground indicators for D.C. circuits when the switch button is pushed. The left light connects the positive side of the line and the right the negative. They are in series and grounded between them. A ground on one side would cause the light on that side to go dead thus limiting the trouble to one side of the line at least. Under normal conditions the substation is operated from the interlocking tower under supervision of the power director.





Substation Control Board

The substation control board also contains a kilowatthour meter. This meter is connected to a potential transformer on the 132 KV side of each transformer in such a way as to add up the total energy supplied to the substation since it began operation. In addition to that there is a voltmeter on the board which may be connected to either bus section 24 or 25 by turning a dial. This meter has a maximum of 15,000 volts, but normally reads 12,000 volts.

There are also two dials on the board which determine the potential transformer to which the relays on the board are connected. The left dial connects the relays on the left of the board to either P24 or P25 while the right dial connects the relays on the right of the board to either P24 or P25. Under normal conditions the left dial is on P24 and the right on P25, but if anything should happen to put one of the potential transformers out of service, then all the relays could be operated from the other transformer.

On the extreme right of the switchboard there are several double throw knife switches. There are two panels of these, the left being a D.C., panel and the right an A.C. panel. The switches on the D.C. panel control groups of switches and breakers. For example one switch controls 1, 1H, 1L, and 12 thus isolating transformer 1 completely. One double pole double throw switch on the D.C. panel throws the entire switch control over to the switchboard in the interlocking tower. When under tower control a switch handle turned in the substation will not operate the switch. The D.C. panel also contains a voltmeter which reads the voltage across the batteries. The panel also has ground detector lights similar to those on the tower board.
On the A.C. panel there is a double pole, double throw switch which throws the motor-generator set onto either S24 or S25 as desired. Another such switch changes the lighting from A.C. to emergency lighting by batteries. There is also a switch to control an oil purifier when used and another to control the

Back of Substation Control Board

motor-generator set.

OPERATION

Under normal conditions the substation makes use of both 132 KV lines 1 and 2 without the tie between them. Therefore switches 124, 224 and 21 are closed while 12 is open. All four transformers are normally used so that all "H" switches and "L" breakers are closed. The two 12 KV buses are usually tied together so BB is closed. Thus the trolley buses fed from separate 132 KV lines are tied together. When electrification is completed along the freight line to Potomac Yards all JRA breakers will normally be closed. At present, however, these trolleys, 1 and 2 south, are still being worked on, so breakers 2501 and 2502 are open and the line is grounded at the "T" switches. All other JRAs are normally closed. Likewise 132 KV line 1 is being worked on between Landover and Capital Substations so that switch 125 is open and 125G is closed. Capital is at present fed by line 2, switch 225 being closed. When all lines are completed 125 will also normally be closed.

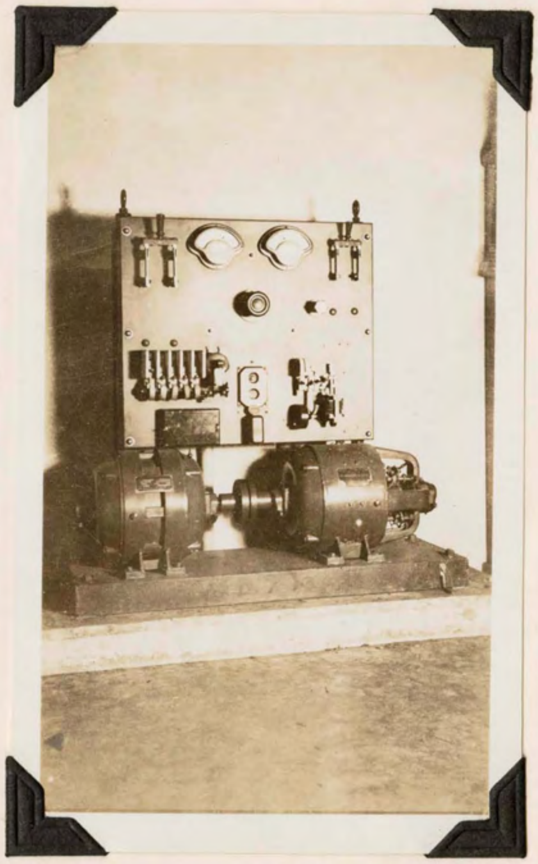
In case of trouble the several possible combinations make it possible to keep both 12 KV bus sections alive unless trouble arises with the bus itself. If, for example, 132 KV line 1 has trouble and cannot be used, line 2 feeds both 12 KV buses trough 2 and 2A. If it is desirable to use all four transformers under such conditions, that is accomplished by tying the high side buses together with switch 12. This would also allow feeding south on both lines if so desired. An interesting situation has already arisen in this connection. A kite with a tinfoil winding on it got tangled in line 2 at Bowie and because lines 1 and 2 were connected at Loudon Park Substation, south of Baltimore, every "L" breaker opened from Loudon Park to Capital thus cutting off all the power in each substation. However, Loudon Park was north of the

connection between lines and was still operating. All sectionalizing switches in the trolleys were closed so that Loudon Park fed all the way through to Washington. Since there was no heavy load on the trolleys at the time all trains were able to operate as usual. Not only were the trolleys kept alive but all the motor-generator sets were kept in operation by back feed from the trolley to the 12 KV buses and through the service transformers which operate the motor-generator sets. The signal generators were likewise kept running so the signals were kept up. All substations were very quickly placed back in operation by disconnecting the 132 KV lines at Loudon Park and feeding through on line 1. Line 2 was kept out of operation and grounded by 224G until the kite string was located and removed. This presented an unusual circumstance which was easily met because of the thorough design of the system.

DIRECT CURRENT SUPPLY

As was mentioned before, the control of the substation is accomplished by use of a D.C. power supply. There is an excellent reason for this use of D.C. instead of A.C. for control. If for some reason the main power supply to the station is cut off, all the A.C. power is gone and there would be no means of controlling switches and breakers other than manually. However with D.C. controls, the power can always be taken from batteries in case the A.C. is lost. The substation has sixty cells in series, each cell giving 2 volts, making a total of 120 volts. These are Gould lead storage batteries and are located in a small room in the control building. The total capacity is about 300 ampere-hours.

However the main D.C. supply is obtained from a motor-generator set which gets its power from the service transformers. It consists of an



Motor-generator set for D.C. Control

A.C. motor rated at: 7.5 HP-110V-75A-1450 RPM-25 cycles A.C.-continuous duty; and a diverter pole D.C. generator rated at: 5KW-140V-35.7A-1450 RPM. Although this generator is rated at 140 volts it is constructed with a shunt field rheostat to regulate the voltage to any desired value. Although 115 to 120 volts is all that is necessary to control the station the terminal voltage of the generator is usually kept about 129 volts so the batteries which float on the line will be charged whilenot in use. This system keeps the batteries up and ready for duty in addition to supplying the necessary power for control. The motor is equipped with a starting coil, a no-voltage release, and a heat element to release the motor when overheated. The generator is equipped with a relay which prevents it from taking load until the voltage is sufficiently high and a voltmeter which reads the terminal voltage. This motor-generator set runs continuously unless the power is cut off or it is in need of repairs.

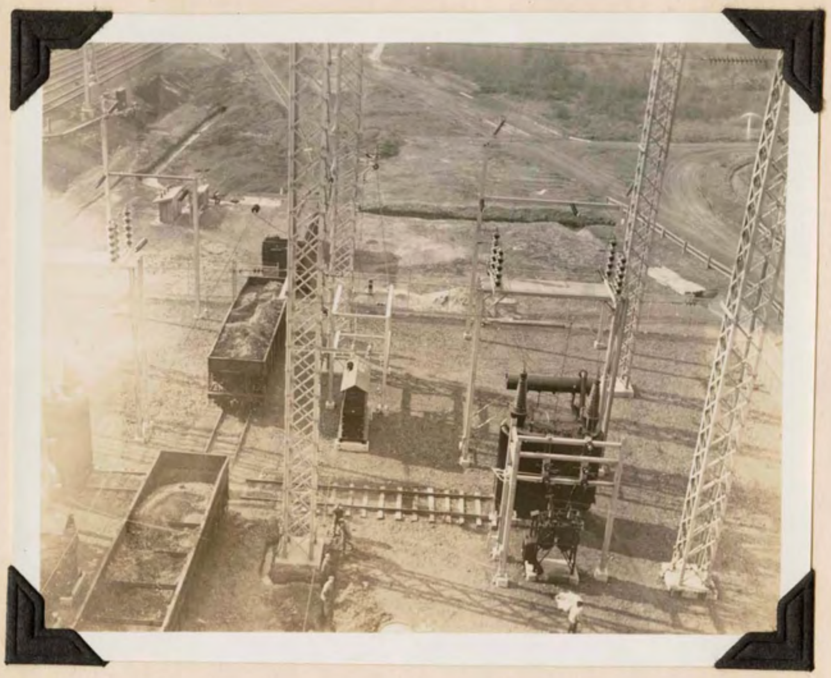
EQUIPMENT

It seems that the Pennsylvania Railroad authorities who had charge of the contracts for the substation equipment decided it would be the best policy to split up the contracts to the different firms as evenly as possible and thereby satisfy them all. Therefore in going through the substation equipment this will be noted. The G.E. equipment consists mainly of switches, large and small transformers, and JRA high speed circuit breakers. The Westinghouse equipment consists mainly of the oil circuit breakers ("BB" and "L" breakers) and the switch control boards. The Allis-Chalmers Company furnished large and small transformers. Relays were made by various firms. Thus the contracts were split quite successfully.

SWITCHES

All twelve switches on the high side of the substation are double pole, single throw, D.C. motor-operated 132 KV switches of the horn-gap type. These include the four line switches , 124, 224, 125, and 225, as well as the four ground switches, 124 G, 224G, 125G, 225G. It also includes the switches on the high side of each transformer, 1H, 1AH, 2H, and 2AH. Each of the above twelve switches is separately motor-operated. Because of its importance in tying the two trolleys of the island section together, the 11 KV switch L12 had to be controllable from the switchboard. Therefore it was also made a motor operated switch. The motors are D.C. compound motors rated at: $\frac{1}{2}$HP-115V-5.6A-1140 RPM-$\frac{1}{2}$ hour duty. These motors are thrown directly across the D.C line from the motor-generator set when the switch control handle is turned. The mechanism for operating these motors contains a limit switch which automatically cuts off the motor when the switch reaches the desired position. Also to prevent a switch from only partly opening or closing a relay operates when the motor circuit is closed to keep it closed until the switch is fully opened or closed. If the switch control handle is turned while a switch id operating it will have no effect until operation is completed.

The remaining switches in the substaion are all manually operated. The switches isolating the "L" breakers are four pole, single throw, 11 KV disconnecting switches. There are four of those. There are also eleven two pole, single throw, 11KV disconnecting switches, one isolating each JRA breaker ("B" and "F" switches) and one isolating the "BB" breaker. In each of the ten trolley feeders there is a single pole, single throw, 11 KV disconnecting switch ("T" switch). All service and potential transformers are isolated by single pole, single throw, 11 KV hook-stick operated switches, four such switches being necessary. This makes a total of 29 manually



Looking down on #2 and JRA breaker 25Y

operated switches.

All the breaker isolating switches are equipped with magnetic locks to prevent opening of a switch while its breaker is closed. Since the object of the breaker is to quench the arc when the circuit is opened it is necessary that the breaker always opens the circuit. If the switch opened first, the resulting arc on the switch would ruin it. Therefore a circuit is arranged such that while the breaker is closed a small plunger fits down into a hole preventing the turning of the switch operating handle. When the breaker opens, the coil circuit of the magnetic lock closes, drawing the plunger up and permitting the operation of the switch.

Transformers

Of the four large step-down transformers numbers 1, 2, and 2A are G.E. transformers, type H, form SDH, 25 cycles, single phase. They are rated:

4500 KVA at 45 C rise for continuous duty

6750 KVA at 60 C rise for 2 hours

13500 KVA at 75 C rise for 5 minutes

Voltage rating: 132,000/12,000 volts

Impedance volts: average 4%

Polarity:- Subtractive

Approx. weight to be lifted when untanking ---------61,000#

Approx. weight of tank and fittings ----------------28,000#

Approx. weight of 6470 gals. #10C transil oil ------48, 000#

Approx. total weight for outdoor installations ----137,000#

These transformers are also equipped with arcing horns making a shorter path from the top of a bushing to the horn than through the bushing for lightning. The gap from horn to bushing on the high voltage side is set at 47.5 inches and on the low voltage side at 6.25 inches.

G.E. transformer #2 with "L" breaker on right

(note part of "H" switch on left)

G.E. transformer #1 with "L" breaker

The other transformer, 1A, is an Allis-Chalmers transformer with the same rating as the others. There is some difference in the weight:

Approx. weight of core and coils ---------67,000#

Approx. weight of case and fittings ------23,000#

Approx. weight of 5470 gals. of oil ------41,000#

Approx. total weight -------------------131,000#

This difference in weight is mainly due to the use of 1000 less gallons of oil.

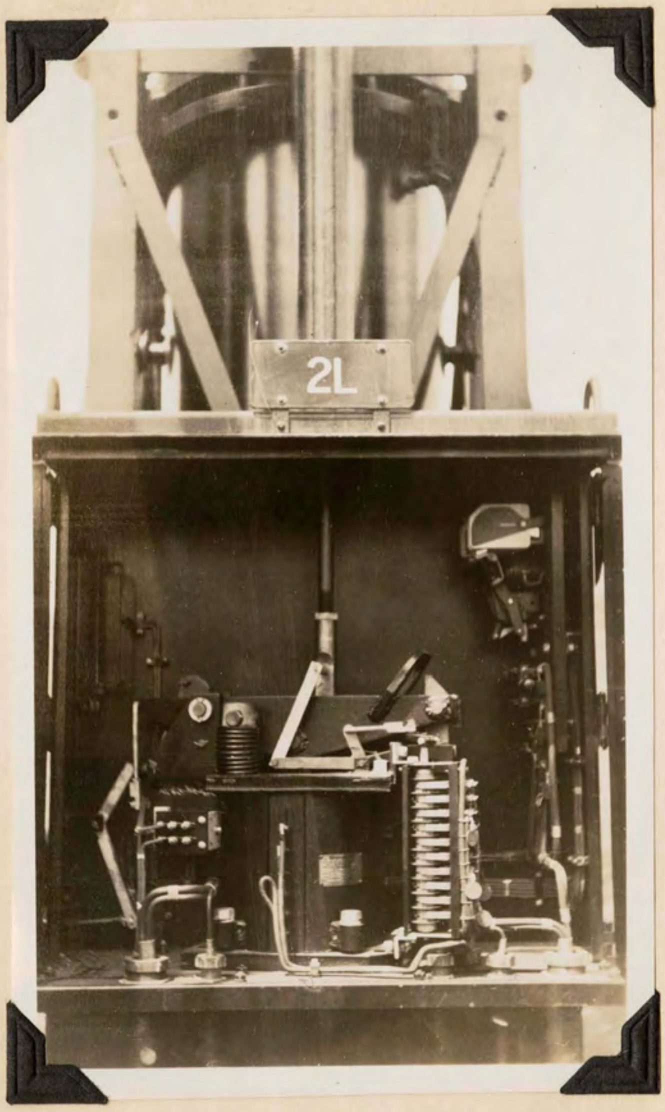
These transformers are very similar in construction and operation. They are oil filled and self-cooled. The G.E. type are cooled by the oil passing through pipes on the outside. These pipes run from top to bottom and offer a large surface to the air, thus cooling oil in the pipes by radiation. The oil circuits slowly through the transformer proper and these pipes on the principle that heat rises. The Allis-Chalmers type works on the same principle only instead of pipes entirely surrounding it there are eight radiators placed in groups of two around it. A valve at the bottom of the transformer permits draining the oil when so desired. The large tanks on top of the transformers are oil reservoirs. This permits expansion and contraction of the transformer oil due to heat changes. On the G.E. type there is a large pipe leading up over the oil tank. This acts as a safety valve for it has a glass plate over the face of it, and a pressure on the plate would break it, thus allowing the oil to pass out of the transformer instead of perhaps causing internal troubles due to pressure. This device is on the oil tank itself on the Allis-Chalmers. Each transformer is equipped with a thermometer which registers internal temperatures but the scale is placed on the outside where it is easily read. The 132 KV lines come into the transformers through large oil filled bushings which extend about four feet above the transformer. On top of the G.E. bushing there is a so-called "fishbowl" which is normally half full of oil. The oil height in the Allis-Chalmers bushing is noted by glass gauge on the top. The

Allis-Chalmers transformer 1A

12 KV lines also come through bushings on top of the transformer, These being much smaller in size. The transformer oil must be of the very purest quality and must contain absolutely no water vapor for it must stand a voltage test of 25,000 volts or more without breaking down. Each transformer has a condenser potential device connected to the high tension bushings. This is used for relay operation which will be explained later. Each transformer also has a set of current transformers for relay operation, consisting of two cross connected current transformers on the high tension side.

In addition to the large power transformers there are two service transformers, S24 and S25. These are 50 KVA Allis-Chalmers transformers with a voltage rating of 13200/220/110. They carry 25 cycle, single phase A.C. and polarity is subtractive. The impedance is about 4%. Each uses 120 gals. of oil being likewise oil filled. They are small enough not to need a cooling system. Instead of being protected by circuit breakers, each of these transformers is fed through a small current limiting resistance and a fuse for protection in case of trouble. This fuse is a type DLC rated at 15 A for 2300V. It consists of a spring coil in a liquid and a excess current flowing through causes it to break. The separation is rapid due to the spring tension and the liquid quenches any arc present. All these features make it an ideal fuse for its use.

There are also two potential transformers, P24 and P25. These are 200 volt-amperes G.E. transformers with a voltage rating of 11000/110. These also run on 25 cycles, single phase A.C. and have a subtractive polarity. These are much smaller than the service transformers and only contain 20 gals. of oil. Each of these is likewise fed through a small resistance and the same type of fuse, the only difference being that it is rated at ½A at 2300V.



Solenoid mechanism of "L" breaker

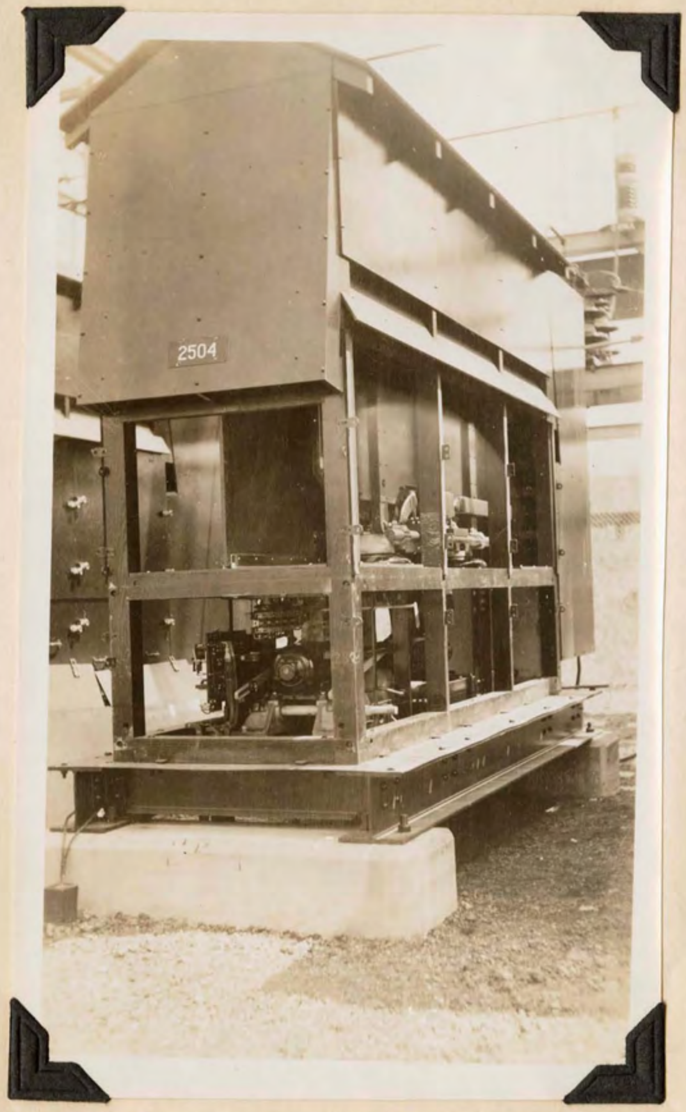
Oil Circuit Breakers

All four of the "L" breakers and the "BB" breaker are Westinghouse, "De-ion Grid" oil circuit breakers. They operate with a solenoid mechanism, the time of opening being estimated at about one or two seconds. They are not called high speed though. The throwing of the switch to close this breaker makes up a relay closing the solenoid circuit. The solenoid draws the plunger down rapidly and when it reaches a certain point it closes an auxiliary switch which energizes a tripping coil which in turn breaks the relay contact and opens the solenoid circuit. This all happens before the plunger reaches the bottom so it travels the remaining distance to the bottom by inertia. This all has the effect of reducing the force with which the plunger hits the bottom. When the plunger reaches the bottom it is held in this position against the action of two powerful springs by a latch. When this breaker is opened either by automatic relay operation or by the control handle a second but smaller solenoid is energized pulling a smaller plunger. This plunger is thrown up rapidly opening the contacts of the breaker. There are two contacts in these oil breakers each in a separate cylinder of oil. These contacts are pulled apart rapidly by the rising plunger. As the contacts separate, oil flows into the space between them thus quenching the arc. There is an exellent reason for using transformer breakers and bus-tie breakers that are slower in action than the trolley feeder breakers. If for some reason one of the trolleys became short circuited the fastest breaker would operate first. Therefore to keep a whole bus section from dropping out the fastest breaker is placed in the trolley feeder where only one trolley will be "lost". Thus the use of the slower operating oil breakers is an aid in keeping the trolleys energized.

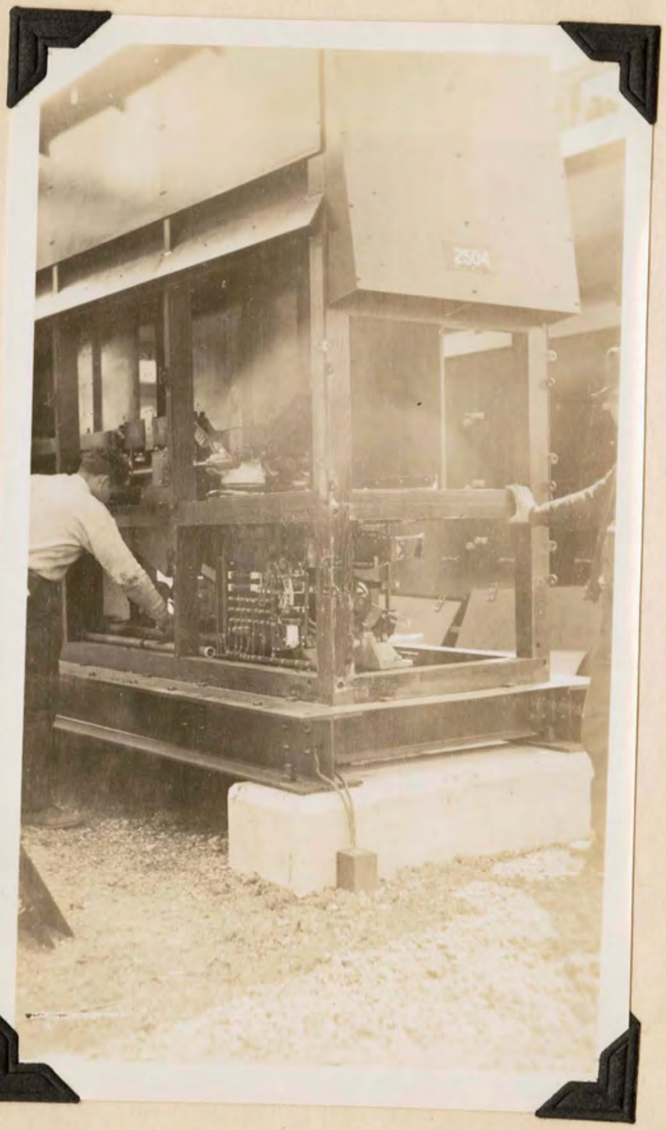
JRA breakers from under low structure

High Speed Circuit Breakers

The G.E. high speed air circuit breakers, type JRA-32, are used for trolley feeder protection. They operate either by impulse trip or relay action. These breakers have two breaks in series consisting of two moving arms held in a closed position by a holding magnet and pulled away from stationary contacts by springs. For breaking the arc there are two arc chutes with four blowout magnets energized by series coils. The arc is pulled up into these asbestos lined chutes by the blowout magnets and is broken in air by stretching. The blowout coils, main contacts, and main bushing current transformers are in series with the circuit to be protected. When the breaker is closed a small laminated armature fastened to the moving contact arm of the breaker bridges the gap of the holding magnet and thus forms a stationary pivot allowing the breaker contact springs to keep the breaker closed. A tripping coil is located in the gap of the holding coil magnet and in close proximity to the small armature. A current flowing in the tripping coil in the proper direction transfers the flux of the holding magnet from the armature to a path through the tripping coil thereby releasing the armature and allowing the powerful springs to carry the contact arm and movable contacts rapidly back to the open position. The holding coil is D.C. excited. The current in the tripping coil is obtained during short circuit conditions by the rectifier action of the saturated core current transformer. The secondaries of the tripping current transformers are D.C. excited, and the primaries of these are connected with opposite polarity across the main bushing current transformer secondary. The latter is located on the bus side of the breaker. This arrangement produces a rectifier action during a sudden increase in current and circulates D.C. in the tripping coil in the proper direction to release the holding armature when the current reaches the proper value. This is called impulse trip and the breaker opens in half a cycle or a fiftieth of a second.



Internal view of JRA breakers
(Arc chutes at top,closing and holding mechanism on bottom)



Internal view of JRA breakers
(Arc chutes at top, closing and holding
mechanism on bottom)

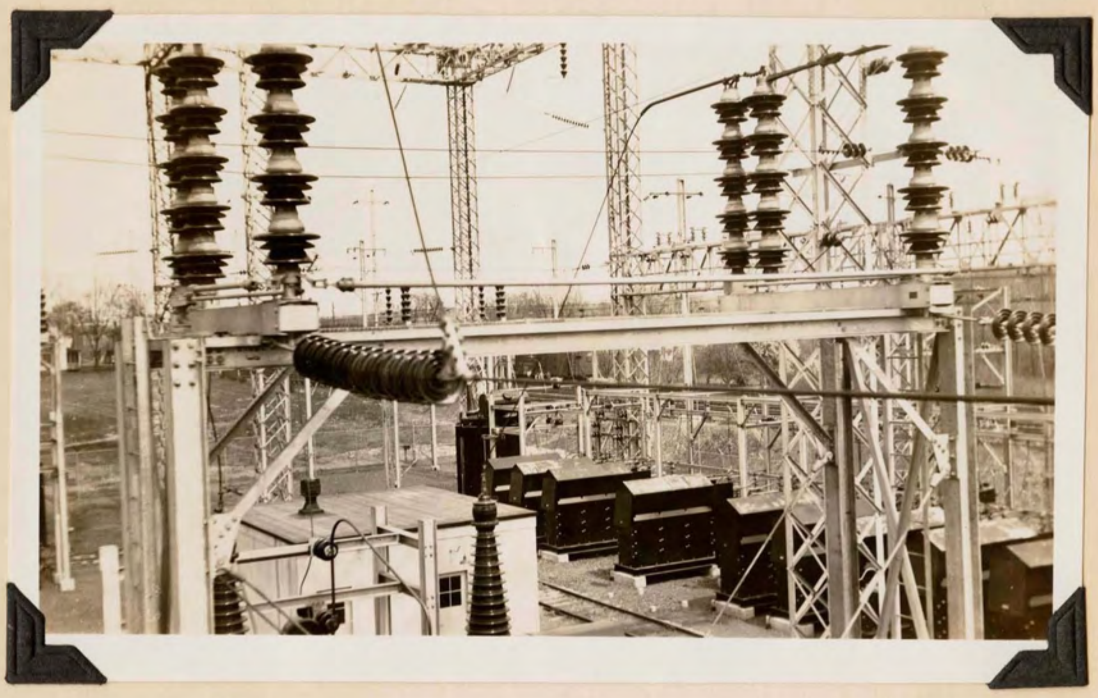
For a gradually increasing overload the breaker is tripped through relay action which opens the holding coil circuit when the overload has reached a predetermined value. The relay is fed from a current transformer on the trolley feeder side of the breaker.

These breakers like the others are operated by control handles on the switchboard. However, these breakers are closed by a motor driven reset mechanism and the breaker is trip free while closing. This allows a circuit under load to be closed by the breaker which still affords protection against short circuit and overload conditions which may exist when the breaker is being closed. This feature is obtained by a combination of contact levers with an arm on which the holding armature is mounted. Gears and cams are arranged so that at any time during the process of setting, the mechanism is free to release. A magnet clutch is used to connect and disconnect the motor from the holding mechanism at the proper time.

These breakers are designed for outdoor installation. They are covered with a weatherproof housing which is removable by parts. The breakers have an overall weight of about 10,000 pounds.

PROTECTION

Perhaps the most outstanding feature of the entire substation design is the thorough protection afforded it against any electrical disturbances within reason. It is so designed that it may continue operation under any ordinary conditions and even the most severe troubles could do but little damage to the station and its apparatus.



Looking down on JRA breakers

(note "H" switch in foreground)

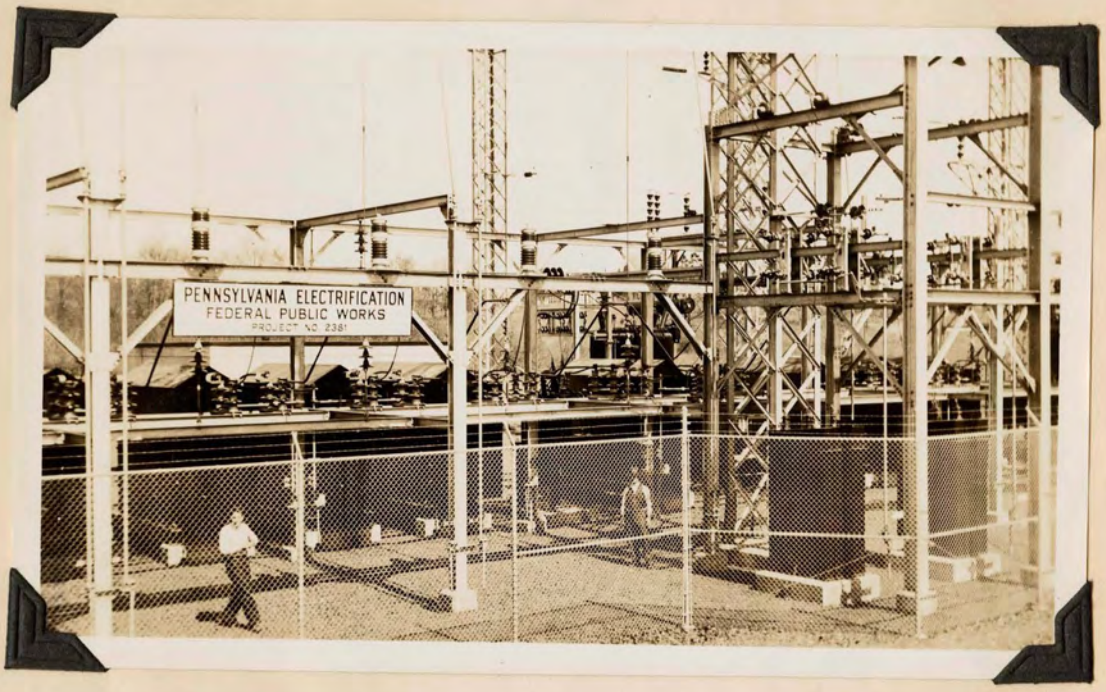
Lightning Protection

The substation has many devices for lightning protection. Eventually a lightning pole of sufficient height to extend far above the highest substation structure will eventually be placed near the center of the station. The 132 KV lines are protected at the substation by arcing rings placed on the end units of insulatore. The lightning wire which runs along the top of the transmission poles also passes through the station. The main transformers are protected on both the high and low sides by arcing horns on all the bushings. The 11 KV lines are protected from lightning by G.E. thyrite lightning arresters placed on the low steel structure and connected with the trolley feeders between the "F" and "T" switches. Each trolley feeder is protected by one arrester.

Relay Operation

The automatic and immediate operation of relays when bus line faults or overloads occur is the most important feature of substation protection. Nearly every possible trouble has been anticipated and relays were arranged to prevent damage by causing the action of some other device made for that purpose.

The 132 KV transmission line ground protection is obtained by means of a type CMV differential relay which receives its potential from condenser potential devices connected to the high tension condenser bushings of the 4500 KVA transformers. This relay has two coils. One receives potential proportional to the line to ground voltage of one wire of the line (A phase), and the other coil, of the other wire of the line (B phase). Each normally gets 55 volts. When a ground occurs on one side of the line the voltage on that side of the potential device approaches zero and the other side 110. This disturbs the balance of the CMV relay causing a contact arm to be drawn to



Low structure from railroad tracks
(note thyrite lightning arresters above sign
and signal breaks on right)

the strong side. This closes the "L" breaker tripping circuit causing the breaker to open and also drops a target in the relay to show on which wire the ground occurred. This is what happened in the kite string incident discussed previously. This action takes place for every transformer.

The 132 KV transmission lines are protected from short circuits by means of the type CR directional control relay. This relay has a power directional element and also an overcurrent element which receives its current from a multiple tap bushing type current transformer. An AV relay receives potential from the bushing potential devices connected to the 4500 KVA transformer. The AV voltage relay shunts out the current coils and open circuits the potential coil of the CR relay on normal voltage. The AV must drop out due to low transmission line voltage and the directional element must be closed before the overcurrent element can start to operate. The operation of the CR relay closes the tripping circuit of the "L" breaker causing it to open.

To protect the 4500 KVA step-down transformers against internal faults a type CA ratio differential relay is used. This is energized by two sets of current transformers, one set consisting of two cross connected current transformers on the high tension side of the transformer, and the other a similar set on the bus side of the "L" breaker. The relay has an operating coil and a restraining coil, there being no current flowing in the former under normal conditions due to a balance between the two currents from the two sets of current transformers. If a fault occurs in the transformer this balance is disturbed and the unbalanced current flows through the operating coil causing the relay to operate. The CA relay has a front and back contact, the front contact being normally open, and the back contact normally closed. If the relay operates, the closing of the front contact

energizes an MC auxiliary relay. A "make" contact of this relay closes the tripping circuit of the "L" breaker which then opens. Another "make" contact closes the alarm bell circuit causing it to ring. A third "make" contact energizes the coil of the ML lockout relay. A fourth "make" contact forms a holding circuit for the MC relay until its coil is shunted out by the normally closed contact of the CA relay. A "break" contact opens in the trip circuit to the "H" switch. The energizing of the ML relay opens the closing circuit of the "L" breaker and "H" switch which cannot be closed again until the relay is reset by hand. The ML also closes a contact in the tripping circuit of the "H" switch which does not complete the circuit because of the "break" contact of the MC relay. As soon as the transformer fault current drops below a value corresponding to the drop-out value of the CA relay, its back contact is again closed and shunts out the coil of the MC relay which becomes deenergized. The break contact is thus closed completing the tripping circuit of the "H" switch which then opens, isolating the faulty transformer from the system. Due to the above connections the "H" switch will not open until the fault current flowing through it is decreased to a safe value.

Protection for the 11 KV buses is similar in operation to the faulty transformer protection. A CA-4 differential relay "makes up" if the load on the two buses differs by more than a predetermined value while the BB is closed. If such is the case the CA-4 is energized from multitap current transformers located on the side of BB away from the bus to be protected. When the CA-4 relay "makes up" it causes the LO relay to be "made up" also. This opens the tripping circuit of every breaker tied to the faulty bus. This includes all JRA and "L" breakers as well as BB. This isolates that bus section and allows the other to continue in operation. The LO relay also opens the closing circuits to all these breakers which cannot be opened again until the relay is reset by hand.

In practice, if a trolley breaker or cable feeder does not open in case of a particularly heavy load, ground, or short circuit, the system is protected by a JD back-up relay which actuates the same LO auxiliary relay as the CA-4 bus differential relay after a definite time delay.

For protection against overload on a trolley feeder an IB-V6 directional overcurrent, undervoltage relay is used. An overload on the trolley causes a corresponding voltage drop and at a predetermined value the relay "makes up". This operates an instanteous auxiliary PQ relay which opens the holding coil circuit of the JRA breakers thus tripping the breaker. For long trolley sections a special distance relay type CEX is used in placed of the IB-V6. The IB-Y6 and CEX relays are fed from current transformers on the trolley feeder side of the high speed breakers.

Preliminary Tests

In order to insure the correct operation of all the substation protectivedevices three different groups of tests were applied before the station was placed in operation. The first of these consisted of preliminary tests without D.C. control and power. This group consisted of: current transformers polarity test, primary and secondary wiring check, circuit breaker and transformer oil test, transformer megger test, power transformer tap changing device check, manual operation of all switching equipment, electrical interlock check, physical check of all relays, setting of lightning arresters.

The second group consisted of tests with D.C. control but no A.C power. These were: D.C. energizing of relay and control board, electrical

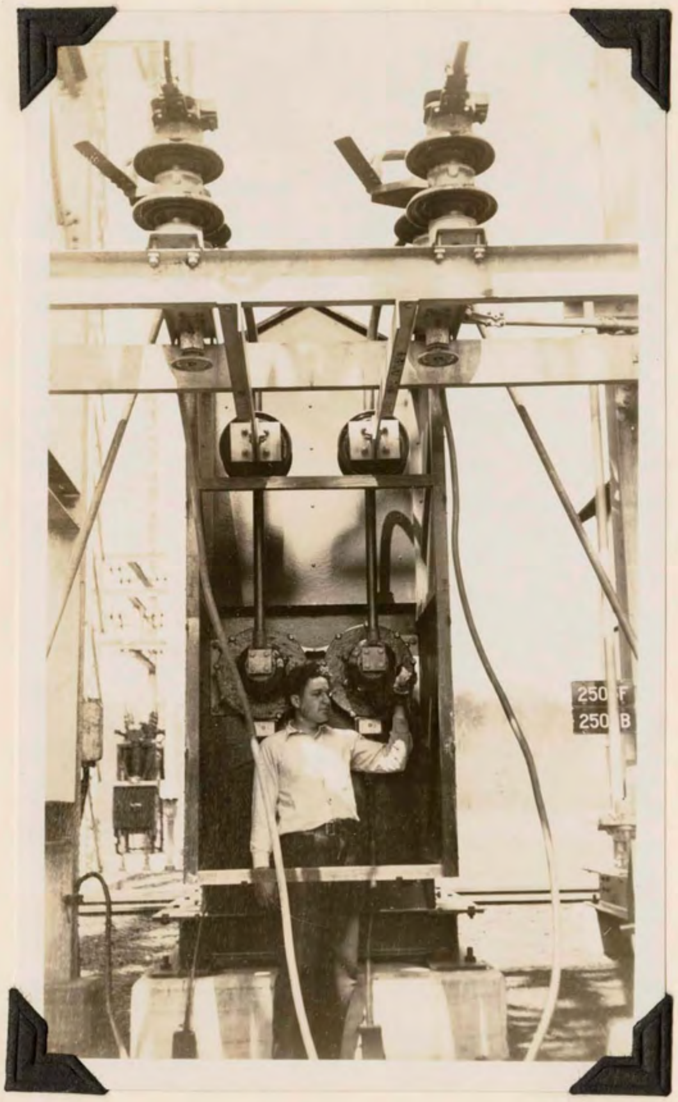
control and indication of apparatus test, electrical interlock test, manual relay operation of apparatus test.

The third group contained test with D.C. control and A.C. power. This included: energizing power transformer test, phase test between 132 KV lines and 11 KV buses, energizing entire substation test, reduced voltage test of all relay operation, full voltage test of all relay operation, phasing and insulation test of catenary system, directional load test. The tests for relay operation were to see if the desired results were obtained when faults of different kinds occured.

Grounds

In order to keep apparatus in a substation from possibly becoming energized due to internal faults, each piece of apparatus including all structure work is grounded. This grounding was done by laying a 4 watt wire about a foot deep in clay completely around the inside of the substation. The wires from the structures to be grounded are 2 watt wires and are tapped onto the 4 watt wire. The 2 watt wires are protected by treated boxes down to the clay to prevent the cinders from acting on the wires.

Before any piece of apparatus may be worked on in the substation it must be thoroughly grounded to take the static voltage off. This is a necessary precaution because the static voltage is sufficiently high to be very dangerous.This grounding is done by special grounding sticks designed for that purpose. They have a hook contact at one end which may be tightened by turning the long handle from the other end. A long insulated cable leads to a plate which may be fastened to a grounded structure nearby. Both leads of the apparatus should be grounded. The "G" switches in the 132 KV lines are for the same purpose.



Cleaning the bushings of a JRA breaker
(note open position of "B" and "F" switches
at top. Also note ground sticks on both sides)

SIGNAL POWER

Landover Substation has very little to do with the power for signals which is fed over a line at 6600 volts-100 cycles and is stepped down to 110 volts at the signals. This 6600 volts is generated both at Bowie and Capital and is fed both ways into Landover. Two lines come in from Capital. These lines pass through Westinghouse circuit breakers at Landover. The main line passes through breaker 352. This line comes in by way of Union Substation and goes through to Bowie. The other line from Capital passes through breaker 352A and is connected to the Union side of the main line. Both of these breakers are isolated by two pole, single throw disconnecting switches. Under normal conditions both of these breakers are open and the signals are fed from both directions. At present 352A is not in operation because of the incomplete freight line. Its isolating switch is open to keep power off the breaker and the line being worked on.

These signal breakers are placed in the circuit to permit a connection between lines in case either Bowie or Capital signal sets fail at any time. This connection is made automatically by the operation of relays. Two MC relays, one on each side of the breaker 352, are operated by current transformers on the corresponding sides. If the power is lost on one side of the breaker, the MC relay on that side operates and closes the breaker-closing circuit. This closes the breaker and allows the power to feed through from the good side. Breaker 352A only has one relay because the other side is connected through 352. A breaker may be reopened by a switch in the interlocking tower.

Signal breaker protection when closed is furnished by the operation of SV, CO, and MX relays in that sequence in case of severe overloads due to shorts. This results in opening the breaker and locking out the clos-

ing circuit until the MX is reset.

CONCLUSION

Landover Substation represents one of the finest examples of modern electrical engineering design. It is so thoroughly protected that the most severe situations are met automatically. Its intricate apparatus is so easily controlled that an attendent at the station is not necessary when it is operating by remote control. It was designed to provide power to the trains in that section at all times,and this requirement is fulfilled remarkably well.

Although it is apparently only a small part of the entire project,this electrical substation plays one of the most important roles in the electrification of the Pennsylvania Railroad.